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Investigations on the occurrence and biology of trematodes of *Sorex araneus araneus* L. in Białowieża National Park

Badania nad występowaniem i biologią przywr *Sorex araneus araneus* L. w Białowieskim Parku Narodowym

The internal parasites of *Micromammalia* are relatively well known. Many publications were devoted to the parasitic fauna of these hosts in different countries and continents. Also in Poland the helminths of micromammalians were investigated in different parts of the country: Białowieża (Sołtys 1949, 1952, 1954, 1957; Kisielewska 1958a, 1958b, 1959, 1960; Pojmańska 1959), Lublin (Furmaga 1956, 1957, 1959), Puławy (Żarnowski 1954, 1955, 1960), Warszawa (Rybicka 1958, 1959), Poznań (Pojmańska 1956, 1957), Wrocław (Dorosz 1958), and Opole (Czapski 1958).

The majority of the papers mentioned has a faunistic or systematic character, and only in few of them there are some data concerning the biology of the parasite, its life cycle, the dynamics of occurrence, and the influence of the environment of the lst and the 2nd order (Sołtys 1954, Prokopič 1956, 1957, 1959).

The aim of the present work was to analyse the abundant material of flukes obtained from the final hosts and from some intermediate hosts to find certain regularities in the occurrence of these parasites in the biocoenosis of Białowieża National Park (BNP) basing on the biology of the trematodes closely connected with the biology and ecology of the final and intermediate hosts. The present work, however, does not exhaust the problems of the biology of trematodes of the common shrew, and therefore further examinations should be carried on.

I would like to express my cordial thanks to Prof. Dr. W. Michajłow for leading this work and for giving me many valuable pieces of advice, and to Prof. Dr. A. Dehnel for the materials collected by the Białowieża Institute for Mammals Research, Polish Academy of Sciences, and for his help to organize the necessary field research in Białowieża. I offer also my thanks to Prof. Dr. E. Żarnowski and Dr. A. Sołtys for allowing me te see Dr. Sołtys' materials from the Dept. of Parasitology, Agricultural College of Lublin, and for the discussion of systematic problems.

Materials and methods

The materials for the present study include the trematodes of *Sorex araneus araneus* L. collected by the Białowieża Institute for Mammals Research, and the larval forms collected by myself from different terrestrial snails in BNP. 805 specimens of *Sorex araneus araneus* were elaborated in the years 1955, 1956, 1957, and 1958, and the following trematodes were found: *Brachylaime fulvum* Dujardin 1843, *Pseudoleucochloridium soricis* (Sołtys 1952) Pojmańska 1959, *Opisthioglyphe* (*Rubenstrema*) *exasperatum* (Rudolphi 1819) Dollfus 1949, *Opisthioglyphe* (*Rubenstrema*) *opisthovitellinus* (Sołtys 1954) Prokopič 1959, and *Opisthioglyphe (Opisthioglyphe) sobolevi* Shaldibin 1953.

Common shrews were collected in different collecting areas of the Białowieża Forest into the Zimmer cylinders (Borowski et Dehnel 1952) which were emptied once or twice a day to have a fresh material. All the observations and measurements of adult trematodes were made on fixed material.

Seventeen species of terrestrial snails* from two biotopes were examined for the larval forms of trematodes in 1957 and 1958. The snails were collected in the late spring, in summer and in autumn. The data from winter and early spring are lacking because of difficulties in collecting snails in these periods of the year. Table I indicates the total number of examined snails collected in two different biotopes: *Querceto carpinetum* Karpiński 1949 and *Caricetum* Karpiński 1949.

4428 snails were examined in two years and the majority of them was found to be free from parasites. Two metacercariae of trematodes parasitizing a common shrew: metacercaria of *Brachylaime fulvum* and that of *Pseudoleucochloridium soricis* were found in the examined snails**. The method of examining snails and metacercaria has been given before (Pojmańska 1959).

Occurrence and biology of trematodes

Brachylaime fulvum Dujardin 1843***

Syn.: *Brachylaima fulvum* Duj. 1843, *Distoma migrans* var. *a* Duj. 1845, „*Brachylaemus fulvus* (Duj. 1843)" (Blanch. 1847), *Harmostomum dujardini* Baer 1928, *Panopistus europaeus* Sołtys 1952, *Brachylaemus oesophagei* Shaldibin 1953, „*Brachylaemus falva*" Duj. (Prokopič 1959).

Morphology: The well developed metacercariae and the young ones with a tail were described in my previous paper (Pojmańska 1959). The

* The specific diagnosis of the snails was checked by Dr. Riedel from the Zoological Institute, Polish Academy of Sciences, Warszawa, for which I am expressing my thanks.

** Besides the metacercariae, there were found in few snails the sporocysts and cercariae of the family *Brachylaimidae*. The present study does not comprise them because it was impossible to determine their specific systematic position.

*** In the present paper I am using the specific name which was given to this species for the first time by Dujardin 1843. The question of the priority of this name and the synonyms of *B. fulvum* are discussed accurately by Kruidenier et Gallicchio 1959.

T a b l e I

Snails collected in various biotopes in Białowieża National Park

Species	Total	Forest	Meadow
Carychium minimum Müll.(Ellobiidae)	8	8	
Succinea putris (L.) (Succineidae)	1499		1499
Cochlicopa lubrica (Müll.) (Cochlicopidae)	32	5	27
Goniodiscus rotundatus (Müll.) (Endodontidae)	218	218	
Goniodiscus ruderatus (Stud.) "	272	272	
Vitrea cristallina (Müll.) (Zonitidae)	27	24	3
Vitrea contracta (West.) "	2	2	
Perpolita petronella (Pfr.) "	7	7	
Zonitoides nitidus (Müll.) "	724	574	150
Vitrina pellucida (Müll.) (Vitrinidae)	13		13
Euconulus fulvus (Müll.) (Ariophantidae)	29	29	
Eulota fruticum (Müll.) (Eulotidae)	320	20	300
Zenobiella rubiginosa (Schm.) (Helicidae)	22		22
Perforatella bidens (Chemn.) "	680	4	676
Clausiliidae sp. sp.	502	484	18
Limacidae sp. sp.	22	22	
Arionidae sp. sp.	51	51	
Total	4428	1720	2708

T a b l e II

Measurements of metacercariae and adults of B. fulvum

Organs	Metacercaria	Adult
Length	1.0 - 1.45	2.0 - 3.1
Width	0.4 - 0.48	0.36 - 0.50
Oral sucker	0.10 - 0.18 × 0.14 - 0.19	0.18 - 0.22 × 0.17 - 0.23
Ventral sucker	0.16 - 0.22 × 0.16 - 0.22	0.21 - 0.26 × 0.18 - 0.23
Pharynx	0.04 - 0.08 × 0.04 - 0.08	0.11 - 0.13 × 0.12 - 0.14
Testis I	0.04 - 0.05 × 0.04 - 0.06	0.11 - 0.15 × 0.07 - 0.13
Testis II	0.03 - 0.07 × 0.03 - 0.08	0.11 - 0.16 × 0.09 - 0.13
Ovary	0.03 - 0.05 × 0.03 - 0.05	0.12 - 0.16 × 0.09 - 0.16
Cirrus pouch		0.18 × 0.05
Eggs		0.027-0.030 × 0.013-0.018

adult trematode is similar to the larval form (Table II). It is about 3 times bigger than metacercaria. The cuticle is distinctly armed with spines which reach the level of the hind margin of the oral sucker or extend even further. The ventral sucker always bigger than the oral one, the ovary and testes

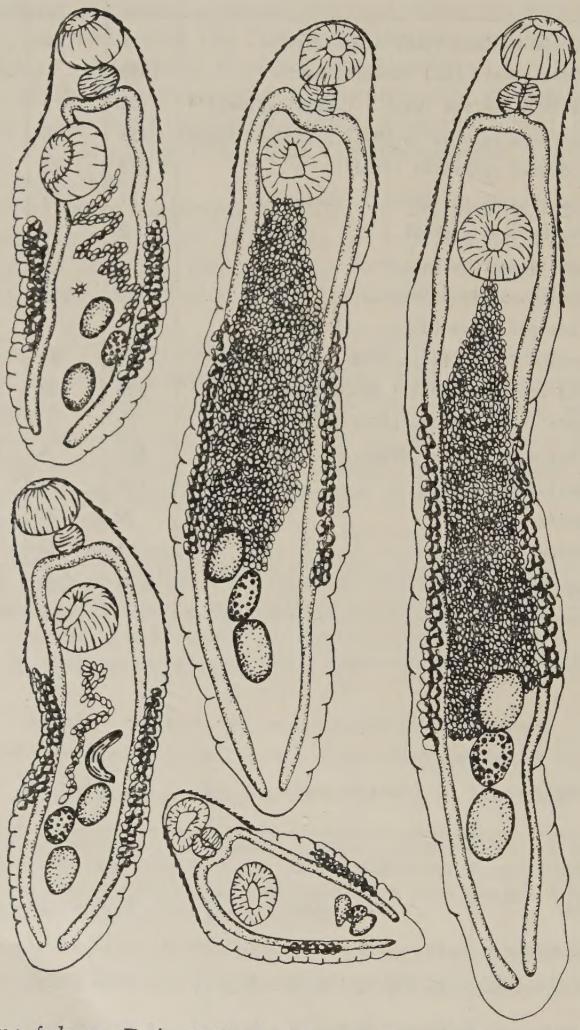

Fig. 1. *Brachylaime fulvum* Duj. 1843. Specimens of various age from the intestine of the same individual of *Sorex araneus araneus*

almost spherical, the anterior margin of vitellary glands shifted forward but never reaches the ventral sucker. The hind margin of vitellary glands reaches the level of the ovary, sometimes the hind margin of the front testis. The uterus, filled with many small eggs, lies in the middle part of the body, from the level of the ovary to the hind margin of the ventral sucker. Sometimes it covers the

ventral sucker but never oversteps its front margin. The cirrus pouch and the genital pore are in adult specimens indistinctly visible because they are covered by a thick layer of eggs.

The dimensions of my specimens of *B. fulvum* do not differ from those of other authors.

Development: The life cycle of *B. fulvum* is not yet totally known. In the literature there are not any data concerning its intermediate hosts. Only Baer 1928 while describing *Harmostomum dujardini* mentioned that he had found metacercariae similar to the adult trematode described in *Agriolimax agrestis* (L.). However, he does not give neither an exact description nor the drawing of the metacercaria. Therefore, one is not sure whether he dealt with metacercaria of this species.

In BNP the larva of *B. fulvum* was found in *Zonitoides nitidus* and, in one case, in *Goniodiscus rotundatus*. In these snails only metacercariae were found, in few cases very young ones, with a rudimentary tail, in the majority, however, they had well developed internal organs. Sporocysts with cercariae were not found. The number of metacercariae in one snail was not great: most often one or two, sometimes more, up to six. Because the number of cercariae in sporocysts of *Brachylaimidae* is usually very high, one can draw the conclusion that *Z. nitidus* is not the only intermediate host of this trematode. Most probably there are two intermediate hosts in *B. fulvum*. Sporocysts with cercariae would develop in the first host, and then the cercariae would migrate to the external environment and attack the second host. *Z. nitidus* is this second intermediate host in Białowieża conditions. Among the representatives of *Brachylaimidae* such kind of development, with two intermediate hosts or even with two specimens of the same snail species, is known (Joyeux, Baer et Timon-David 1934, Krull 1933, Ulmer 1951, Villella 1954).

It seems to me that the development of *B. fulvum* is possible only in the environment with a high humidity, because I did not find this trematode in Turew, near Poznań, in dry areas (Pojmańska 1957). Prokopič 1959 regards this fluke as a parasite connected with the forest-steppe areas.

Intermediate hosts: In BNP the metacercariae of *B. fulvum* occurred in 34 out of 724 examined specimens of *Z. nitidus*, and in 1 out of 218 *Goniodiscus rotundatus*. Owing to Mr. S. L. Kazubski, who offered me his materials, I was able to determine few other intermediate hosts of this trematode from other parts of Poland* (Table III).

Thus, the list of the intermediate hosts in Poland includes 6 species of terrestrial snails. However, it seems to me that the specificity of metacercariae of *B. fulvum* is quite narrow. In Białowieża only *Zonitoides nitidus*, and in one case *Goniodiscus rotundatus*, were invaded by this trematode. Also in Mazury and Kaszuby just this snail species serves as the intermediate host. In the mountains, where *Z. nitidus* occurs sporadically and only in not very high regions, related snail species of the same family, characteristic in these mountain areas, used to be the intermediate hosts of the fluke. Basing even on these limited data, it seems to me that *Aegopinella epipedostoma* is the

* I am expressing my thanks to Mr. S. L. Kazubski for these materials.

main intermediate host in the mountain areas. Although this snail species was examined in smaller numbers than *Oxychylus orientalis*, the percentage of invasion in this snail was higher.

Table III
Intermediate hosts of B. fulvum in Poland

Host	Białowieża			Warszawa			Mazury			Kaszuby			Karpaty		
	Exam.	Inved.	%	Exam.	Inved.	%	Exam.	Inved.	%	Exam.	Inved.	%	Exam.	Inved.	%
Zonitoides nitidus (Müll.)	724	34	4.7	444	1	0.2	44	1	2	23	1	4	17	0	0
Oxychylus orientalis (Cless.)													410	3	0.7
Aegopinella epipedostoma (Fagot)													84	5	5.9
Goniodiscus rotundatus (Müll.)	218	1	0.5							44	1	2			
Euconulus fulvus (Müll.)	29	0	0	19	0	0	1	0	0	7	0	0	11	1	9
Deroceras sp.										19	3	13.8			

Final hosts: According to the data from the literature, the following species are the final hosts of *B. fulvum: Sorex araneus araneus* L., *S. minutus* L., *Crocidura russula* Herm., *C. suaveolens* Pall., *C. leucodon* (Herm.), *Neomys fodiens* Schr., and *N. anomalus milleri* Mottaz.

Table IV
Occurrence of B. fulvum in BNP

Species	1949			1950			1955			1956			1957			1958		
	Exam.	Inved.	%	Exam.	Inved.	%	Exam.	Inved.	%	Exam.	Inved.	%	Exam.	Inved.	%	Exam.	Inved.	%
S. araneus araneus	412	8	1.94				344	32	9.3	142	19	13.3	146	63	43.0	173	72	41.0
Sorex minutus	590	0	0	159	3	1.9												
Neomys fodiens	218	7	3.22	70	0	0												
N. anomalus milleri	71	0	0															

The extensiveness of invasion in Białowieża, based on the material of Sołtys (1949—1950) and my own data (1955—1958) is represented in Table IV.

This table shows that the adult *B. fulvum* may parasitize many representatives of the European *Soricidae*. Nevertheless, *Sorex araneus araneus* seems to be the main host of this parasite. The extensiveness of invasion is about 40%, and the intensivity of invasion is not high, 2 to 3, and sometimes over 10 specimens in one common shrew.

The possibility of parasitizing several species of the family *Soricidae* is probably connected among others with the biology and ecology of the intermediate host. Judging from my observations, *Zonitoides nitidus* may appear in quite different biotopes in the whole area of Białowieża Forest and may serve as food to both xerophilous and hygrophilous species of *Insectivora*.

Seasonal dynamics: The first analysis of occurrence of adult trematodes of *Soricidae* in BNP in the year's cycle was done by Sołtys 1954; also my materials allow me to draw some conclusions as regards metacercariae (Table V).

Table V

Invasion of Zonitoides nitidus with B. fulvum

Month	1957			1958		
	Exam.	Invad.	%	Exam.	Invad.	%
January						
February						
March						
April	28	3	10.7			
May				41	1	2.4
June	168	12	7.1	135	7	5.8
July	169	11	6.7	17	0	0
August						
September	143	0	0			
October	13	0	0			
November						
December						
Total	521	26	5.0	193	8	4.1

The snails were collected mainly in summer, and the reason of the lacking materials from the late autumn, spring and winter were some difficulties in obtaining it.

The extensiveness of invasion of snails with metacercariae is as a rule low and the invasion of *Z. nitidus* amounts 4.7%. The invaded snails were found throughout the whole period of investigation if the number of examined snails

was large enough. It seems that this situation is also unchanged in winter. Because of their way of life, the snails can not be infested in winter. However, many mature metacercariae were found in spring, what indicated that the snails had been already invaded before winter and the metacercariae had to overwinter in their intermediate hosts.

The materials concerning the occurrence of the adult trematode in common shrew were collected within 4 years. Not all material of the years was well elaborated, but some conclusions may be drawn very distinctly.

The collecting of mammals was carried on by the Białowieża Institute for Mammals Research regularily throughout the whole year. Also *B. fulvum* was found in a common shrew throughout the whole year. Although the rate of invasion throughout the whole year is on a quite high level (on the average 35%) it undergoes some fluctuations in different months. In one generation of a common shrew (from June of one year till December of the following year) there appear an increase of invasion of young animals in summer months, a small decrease of invasion in November or December, again a small increase between December and March, and a distinct fall of the percentage of invasion in March, i. e., in the period of the sexual maturation of a common shrew. In animals, which overwintered, the percentage of invaded specimens again increases and remains on a fairly high level till the death of the generation (Diagram 1).

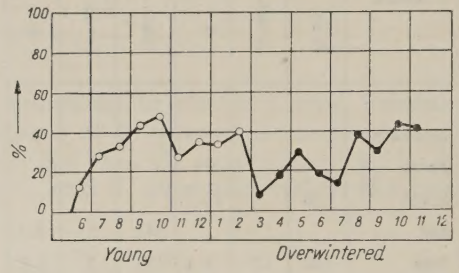

Diagram 1. Curve of invasion of one generation of *S. araneus araneus* with *Brachylaime fulvum* Duj. (total material)

I would like to make a reservation that all the quantitative and percentage data in the present paper are not very exact and probably deviate a little from the relations in nature. First of all, not all the years are equally comparable, because the materials were collected in 1957 and 1958 much more accurately than in the previous years. Secondly, the materials from some months are too scanty to calculate the percentage of invasion, and therefore to each of the diagrams a table, illustrating the concrete material, is included. In spite of those reservations, some regularities are quite distinct.

Diagram 1 is based on the total material from the whole investigation period (young and overwintered animals examined in separate months during four years) to enhance the appearing phenomena. The curve of invasion of overwintered animals is running fairly unregularly, but still it shows an in-

creasing tendency. It should be born in mind that in this period of time the overwintered animals gradually die off and the number of collected specimens is small and not equal in different months. This is probably the reason of the irregular course of the curve.

The increase of extensiveness of invasion in summer months both in young and overwintered animals sugests that the age of a common shrew does not have any big influence on the possibility to be infected with this trematode. This is also corroborated by the occurrence in both age groups of quite young trematodes coming from a recent invasion. The analysis of the material did not show any relations between the extensiveness of invasion and the sex of the host, either.

The phenomenon of the increase and the decrease of the extensiveness of invasion indicates the possibilities of reiteration of invasion with the same trematode species within the year.

My investigations show that trematodes of different degree of maturity occur in a common shrew within a year, and therefore the invasion of the final host can appear throughout the whole year. Thus, the invadable metacercariae must also appear in the snails throughout the whole year. Since the shrews feed in winter mainly on food found under the litter, where also snails are overwintering, they can be invaded even in winter. Doubtlessly there is a certain relationship between the invasion of snails with the eggs of the trematode and the year season. The snails do not have in winter an active way of life, that is why the beginning of a new life cycle can not appear in this season. However, from the moment when the snails, first intermediate hosts, start to go out of under the litter and have the possibility to eat eggs appearing in the feces of the shrew, the life cycle of *B. fulvum* can start anew throughout the whole spring, summer and autumn.

So far the investigations did not show the duration of the whole life cycle of this trematode; one can only suppose that its development is fairly fast. It is shown by the structure of a mature metacercaria in an intermediate host which has very well developed all internal organs and the further maturation relies on a certain growth and egg production.

In *S. araneus* a successive coinvasion may occur. In same shrews a number of trematodes on various stage of development was found, in others — flukes on the same stage of development occurred. This phenomenon should not be attributed to the hampering of the development of a part of population as a result of overdensity, but to the various age of trematodes.

Pseudoleucochloridium soricis (Sołtys 1952) Pojmańska 1959*

Syn.: *Leucochloridium soricis* Sołtys 1952.

Morphology: The description of a mature metacercaria was given in a previous paper (Pojmańska 1959). In the later materials I found also young forms which, similarly to the other representatives of the subfamily *Brachylaimidae,* possessed a tail.

The adult trematode does not much differ from the metacercaria. The size of the trematode and of all internal organs enlarges slightly, the parasite, and

* To the synonyms also *L. skrjabini* Shaldibin 1953 should be included (Pojmańska 1959).

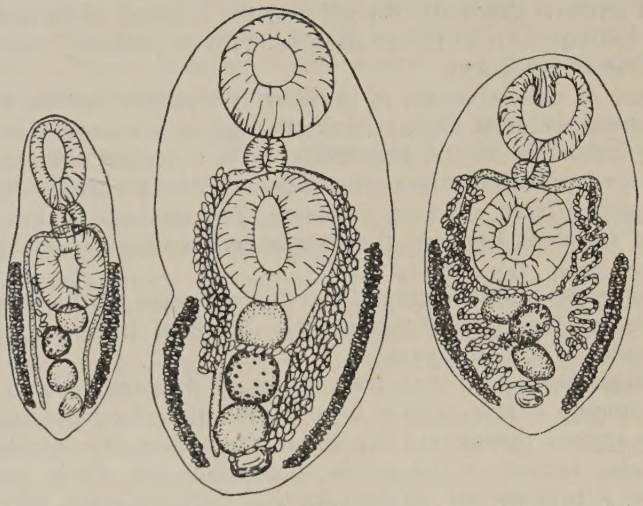

Fig. 2. *Pseudoleucochloridium soricis* (Sołtys 1952) Pojmańska 1959

Table VI

Measurements of P. soricis and L. skrjabini

Organs	Pseudoleucochloridium soricis		Leucochloridium skrjabini (after Shaldibin)
	metacercaria	adult form	
Length	0.72 - 1.6	0.79 - 1.24	0.95 - 1.53
Width	0.52 - 0.96	0.51 - 0.66	0.47 - 0.63
Oral sucker	0.21 - 0.32 × 0.22 - 0.43	0.22 - 0.32 × 0.22 - 0.30	0.20 - 0.48
Ventral sucker	0.24 - 0.46 × 0.25 - 0.49	0.20 - 0.35 × 0.18 - 0.36	0.22 - 0.48
Pharynx	0.07 - 0.12 × 0.10 - 0.16	0.10 - 0.11 × 0.09 - 0.13	0.10 - 0.15
Testis I	0.06 - 0.18 × 0.08 - 0.15	0.11 - 0.15 × 0.10 - 0.15	0.10 - 0.11 × 0.36
Testis II	0.06 - 0.13 × 0.06 - 0.15	0.10 - 0.15 × 0.11 - 0.15	0.15 - 0.15 × 0.15 - 0.17
Ovary	0.05 - 0.16 × 0.07 - 0.13	0.11 - 0.17	0.08 - 0.15 × 0.08 - 0.14
Eggs		0.02 - 0.03 × 0.013-0.016	0.027-0.015

especially its hind part, becomes longer; therefore the centre of the ventral sucker is shifted to the front part of the body. Genital organs, contrary to metacercaria, have a fairly permanent size, shape and arrangement. Testes and ovary spherical or slightly elongated, ovary a little smaller than the testis. The arrangement of vitellary glands does not change. Uterus has the same course as in metacercaria and fills out the entire free fields between the vitellary glands, but not covering the ventral sucker and the genital glands (Fig. 2, Table VI). In this table for a comparison there are also given the dimensions of *L. skrjabini* Shaldibin 1953.

The included dimensions do not sufficiently differ from those of other authors.

Development: The whole life cycle of *P. soricis* is not known. Those metacercariae found in Białowieża were in different stages of development, some of them were still very young and posessed a tail. This is one more evidence that *P. soricis* can not be included to the genus *Leucochloridium*. It can be supposed that the development of this trematode is similar to that of other representatives of *Brachylaiminae*.

The maturation of trematodes in the final host, although the metacercaria is much advanced in its development, probably does not proceed to fast because the number of young flukes is fairly large in comparison with all trematodes found in shrews.

Table VII
Invasion of snails with P. soricis

	Snail species	1957			1958			1959		
		Exam.	Invad.	%	Exam.	Invad.	%	Exam.	Invad.	%
Białowieża	Succinea putris L.	329	9	2.74	117	70	6.0			
	Perforatella bidens (Cherm)	482	5	1.0	198	13	6.7			
	Zenobiella rubiginosa (Schm.)	11	0	0	11	1	9.0			
Karpathians	Perforatella dibotrion Kimak	38	4	10.5	23	0	0	1	1	
	Zenobiella vicina (Rossm.)	5	0	0	4	1		4	0	0
	Lacinaria gulo (Bielz)	16	0	0	69	1	1.5	56	3	5.4
	Iphigena latestriata (Bielz)	14	1	7.1	8	0	0			
	Trichia bielzi (Schm.)	1	1		10	0	0	2	0	0

Intermediate hosts: Metacercaria of *P. soricis* occurred in Białowieża in *Succinea putris*, *Perforatella bidens*, and *Zenobiella rubiginosa*. Besides, it was found in the collection of Kazubski in *Lacinaria gulo*.

Iphigena latestriata, Zenobiella vicina, Perforatella dibothrion, and *Trichia bielzi.* The extensiveness of invasion is shown in Table VII.

Final hosts: In Białowieża *P. soricis* parasitizes (after Sołtys) *Sorex araneus araneus* and *Neomys fodiens;* Stammer 1955 found it also in *Crocidura leucodon.* If *L. skrjabini* is a synonym of this species, *S. minutus* should be included to the list of its hosts.

This trematode occurs in shrews very seldom. The extensiveness of invasion of common shrew in Białowieża is the lowest if compared with other flukes parasitizing this host, and the intensivity of invasion fluctuates between 2 and 3 specimens. The data of Sołtys (collections from 1948—1949) and my own ones (collections from 1955—1958) are shown in Table VIII.

Table VIII
Occurrence of P soricis in common shrew in BNP

Years	Exam.	Invad.	%
1948	2027	16	0.79
1949	412	11	2.67
1955	344	2	0.58
1956	142	0	0
1957	146	0	0
1958	173	3	0.73

Table IX
Occurrence of P. soricis in common shrew in BNP

Month	1955		1956		1957		1958	
	Exam.	Invad.	Exam.	Invad.	Exam.	Invad.	Exam.	Invad.
January	19	0	19	0	13	0	14	0
February	20	0	5	0	11	0	7	0
March	29	0	26	0	7	0	5	0
April	26	0	23	0	6	0	16	0
May	4	0	0	0	10	0	3	0
June	83	0	18	0	16	0	11	0
July	46	0	12	0	20	0	31	0
August	76	2	8	0	25	0	42	1
September	18	0	2	0	5	0	17	1
October	2	0	12	0	12	0	14	0
November	16	0	8	0	7	0	12	1
December	5	0	9	0	14	0	1	0
Total	344	2	142	0	146	0	173	3
Per cent.	0.6		0		0		1.8	

Seasonal dynamics: According to Sołtys 1954 the mature trematode appears in *S. araneus araneus* and *Neomys fodiens* not before July or August, what has been confirmed also by my investigations (Table IX). This trematode occurred exclusively in young shrews.

In *Succinea putris* the metacercariae occurred throughout the whole year except of November, when the number of snails investigated was very low. One can suppose that this phenomenon occurs throughout the whole year because the first metacercariae found in spring were quite mature. Very characteristic was the material collected at the end of April 1960, not included in the table. Due to the long spring coolness, the snails did not yet leave their hiding-places, and all of them were dig out of under a thick layer of litter or soil clefts. The openings ot the snail shells were yet closed. The invasion of snails with metacercariae was very high, up to 20%. Unfortunately, this was the only year in which so early materials were collected.

In *Perforatella bidens* the metacercariae were found only in October and November. However, it should be stressed that just in these months the larger number of these snails was investigated.

Table X

Invasion of various snails with Pseudoleucochloridium soricis

Month	Succinea putris				Perforatella bidens				Zenobiella rubiginosa			
	1957		1958		1957		1958		1957		1958	
	Exam.	Invad.	Exam.	Invad.	Exam.	Invad.	Exam.	Invad.	Exam.	Invad.	Exam.	Invad.
January												
February												
March												
April												
May												
June	96	2	401	4	22	0	72	0	10	0	7	0
July	95	3			2	0						
August			515	42			49	0			2	0
September	128	4	92	15	7	0					2	1
October			162	9	217	2	77	13	1	0		
November	10	0			234	3						
December												
Total	329	9	1170	70	482	5	198	13	11	0	11	1
Per cent.	2.8		6.0		1.0		6.6		0		9	

Zenobiella rubiginosa is elaborated very poorly because only 22 specimens were investigated. The only invaded snail (11 very young metacercariae) was found in September.

The investigations have shown that the mature metacercariae parasitize the main intermediate host, *Succinea putris*, throughout the whole year, and, theoretically, the common shrew has the possibility to be invaded throughout the whole year (Table X). This is also visible in the fairly high percentage of the invaded snails. However, the extensiveness of invasion of the final host is very low, and the trematodes, practically, occur only within 3—4 months in a year. It is possible that it depends on the age of the final host (this trematode was found only in young shrews), or it is connected with the fact that *Succinea putris* is a large snail (1 — 2 cm.) which excrets a big amount of mucus, what is probably not attractive as food of shrews.

Opisthioglyphe (Opisthioglyphe) sobolevi Shaldibin 1953

Syn.: *O. soricis* Pojmańska 1956.

In 1956 and 1957 I gave a description of a trematode found in *Sorex araneus araneus*, which was determined as a new species, *Opisthioglyphe soricis* Pojmańska 1956. These trematodes, and the specimens found in Białowieża, differ from the helminths described by Shaldibin (1953) only by the front

Fig. 3. *Opisthioglyphe (O.) sobolevi* Shaldibin 1953

expansion of vitellaria (Fig. 3) which are joined in their front by a more or less distinct transversal chain (in the Shaldibin's drawing they are distinctly separated). Because of the conformity of all other details of the structure, I consider both forms as identical and the name of *O. soricis* Pojmańska 1956 as a synonym of *O. sobolevi* Shaldibin 1953.

The dimensions of my material from Białowieża and Turew are in agreement with the description of Shaldibin.

Final hosts: *O. sobolevi* was found in Poland so far only in the common shrew, and by Shaldibin also in *Sorex minutus*. It is a fairly common parasite of *Sorex araneus araneus*, and was found in 28 out of 805 (3.47%) specimens investigated. However, the intensivity of invasion is very high, from

Table XI

Maturity stage of O. sobolevi in common shrew in BNP

Month	1955			1956			1957			1958		
	Young	Medium	Mature	Young	Medium	Mature	Young	Medium	Mature	Young	Medium	Mature
January												
February												
March												
April												
May												
June			19					1	147			45
July			18								6	95
August			12						9		3	36
September										1	3	53
October									5			
November									1			
December												
Total			49					1	162	1	12	230

Table XII

Invasion of common shrew with Opisthioglyphe sobolevi in BNP

Month	1955		1956		1957		1958	
	Exam.	Invad.	Exam.	Invad.	Exam.	Invad.	Exam.	Invad.
January	19	0	19	0	13	0	14	0
February	20	0	5	0	11	0	7	0
March	29	0	26	0	7	0	5	0
April	26	0	23	0	6	0	16	0
May	4	0	0	0	10	0	3	0
June	83	2	18	0	16	2	11	1
July	46	0	12	0	20	0	31	4
August	76	5	8	0	25	2	42	7
September	18	1	2	0	5	0	17	1
October	2	0	12	0	12	2	14	0
November	16	0	8	0	7	1	12	0
December	5	0	9	0	14	0	1	0
Total	344	8	142	0	146	7	173	13
Per cent.	2.3		0		4.8		7.5	

a few to several hundreds of specimens. Among the trematodes parasitizing this host, only *O. sobolevi* was found in such large quantities.

Development: Unknown. The attempt of artificial infection of several species of terrestrial snails in Białowieża was not successful. However, there can be given some suggestions as regards the development of this trematode. In the material investigated, almost all the trematodes were completely mature (Table XI) what indicates a notable speed of maturation in the final host. This takes place when metacercaria is very advanced in its development. It is very often connected with the presence of two intermediate hosts. As no metacercariae of this species were found in the terrestrial snails investigated, it is possible that they should occur in water snails and in larvae of water insects which after metamorphosis live on land — similarly to the life cycle of *O. locellus* Kossack 1910 (according to Macey et Moore 1958).

Seasonal dynamics: Table XII shows that *O. sobolevi* occurs in the shrew only between June and November, the extensiveness of invasion fluctuates within particular months in various years (2 to 30%), but there are not any regularities in these fluctuations. They are result in an uneven number of animals investigated in various seasons. No differences were also found in invasion of males and females.

The analysis of the materials have shown that mainly young specimens, born in a given year, are being invaded; overwintered animals were invaded only sporadically. Because *O. sobolevi* was never found in winter and in spring, we cannot draw the conclusion that shrews were invaded before the sexual maturity.

Opisthioglyphe (Rubenstrema) exasperatum (Rudolphi 1819) Dollfus 1949

Syn.: *Distoma exasperatum* Rudolphi 1819, *Distoma rubens* Dujardin 1845, *Echinostomum exasperatum* (Rudolphi 1819) Nicoll 1923, *Distomum exasperatum* (Rudolphi 1819) exempl. *A* et *B* Szidat 1928, *Plagiorchis microti* Sołtys 1949, *Plagiorchis exasperatus* (Rudolphi 1819) Sołtys 1952.

Morphology: The structure of Białowieża specimens does not differ from the descriptions of other authors. My specimens (not flattened) appeared to be a little smaller. Length of trematodes fluctuates within 2.03 and 3.18 mm., width 0.70 — 0.99 mm., oral sucker 0.29 — 0.43 × 0.39 — 0.44 mm., ventral sucker 0.47 — 0.63 × 0.46 — 0.60 mm., pharynx 0.16 — 0.19 × 0.13 — 0.16 mm., ovary 0.16 — 0.20 mm., testis I 0.31 — 0.40 × 0.16 — 0.28 mm., testis II 0.38 — — 0.53 × 0.20 — 0.32 mm., cirrus pouch 0.25 — 0.42 × 0.09 — 0.14 mm., eggs 0.041 — 0.043 × 0.016 — 0.020 mm.

Final hosts: *O. exasperatum* is a fairly common parasite of *Soricidae*. It was found in *Sorex araneus araneus* L., *S. minutus* L., *S. macropygmaeus karpińskii* Dehnel, *Neomys fodiens* Schr., *N. anomalus milleri* Mottaz and *Crocidura leucodon* (Herm.).

The extensiveness of invasion in various hosts, according to Sołtys (collections of 1948 — 1949) and my collections (1955 — 1958), is shown in Table XIII. There is a lack of data for *S. macropygmaeus karpińskii* and *N. anomalus milleri*.

As we see from the table, this trematode may parasitize various *Soricidae*, but *Neomys fodiens* seems to be the most common host. The intensivity of invasion varies from several up to 20 specimens in one host. No relations were found between the invasion and the sex and age of the host.

T a b l e XIII

Occurrence of O. exasperatum in BNP

Host	1948	1949	1955	1956	1957	1958
S. araneus araneus	6.0 %	3.6 %	6.4 %	1.3 %	1.4 %	7.0 %
S. minutus		5.0 %	4.2 %			
Neomys fodiens		8.7 %	4.3 %			

D e v e l o p m e n t: The life cycle is unknown, but we can suppose that, like in majority of *Plagiorchidae*, a water snail is the first intermediate host, and the second one is an insect, the larva of which lives in water and the imago on land.

T a b l e XIV

Invasion of common shrew with O. exasperatum in BNP

Month	1955		1956		1957		1958	
	Exam.	Invad.	Exam.	Invad.	Exam.	Invad.	Exam.	Invad.
January	19	0	19	0	13	0	14	0
February	20	0	5	0	11	0	7	0
March	29	0	26	0	7	0	5	0
April	26	0	23	0	6	0	16	0
May	4	0	-	-	10	0	3	0
June	83	3	18	1	16	0	11	0
July	46	3	12	0	20	0	31	2
August	76	13	8	0	25	1	42	6
September	18	3	2	0	5	0	17	2
October	2	0	12	1	12	1	14	0
November	16	0	8	0	7	0	12	2
December	5	0	9	0	14	0	1	0
Total	344	22	142	2	146	2	173	12
Per cent.	6.4		1.4		1.4		7.0	

The time of the total life cycle is unknown. In the final host the trematode matures probably very long, since in the investigated material there have been found relatively many very young and young forms. Out of 152 specimens, 60 had not any eggs, 8 had small number of eggs, and 84 were totally mature.

Seasonal dynamics: *O. exasperatum*, like *O. sobolevi*, shows a very distinct relationship between the occurrence and the year's season (Table XIV). It occurred exclusively between June and November. That phenomenon and the occurrence of young and adult trematodes in the same host specimen indicate that the shrews become invaded not once but throughout the whole summer-autumn season, and probably not in winter and spring. The late occurrence of this parasite (June) indicates that its life cycle is connected with the year's seasons and probably occurs in two intermediate hosts.

Opisthioglyphe (Rubenstrema) opisthovitellinus (Sołtys 1954)
Prokopič 1959

Syn.: *Distoma exasperatum* (Rudolphi 1819) exempl. C Szidat 1928, *Plagiorchis opisthovitellinus* Sołtys 1954.

Morphology: The structure coincides with the descriptions of other authors. Length of the body 2.68 cm., width 0.70 mm., oral sucker 0.29 × 0.29 mm., ventral sucker 0.43 × 0.43 mm., pharynx 0.14 × 0.13 mm., cirrus pouch 0.25 × 0.17 mm., testis I 0.39 × 0.32 mm., testis II 0.43 × 0.28 mm., ovary 0.20 × 0.24 mm., eggs 0.054 — 0.059 × 0.020 — 0.027 mm.

Table XV

Invasion of common shrew with O.opisthovitellinus in BNP

Month	1955		1956		1957		1958	
	Exam.	Invad.	Exam.	Invad.	Exam.	Invad.	Exam.	Invad.
January	19	0	19	0	13	0	14	0
February	20	0	5	0	11	0	7	0
March	29	0	26	0	7	0	5	0
April	26	0	23	0	6	0	16	0
May	4	0	0	0	10	0	3	0
June	83	2	18	0	16	0	11	0
July	46	2	12	0	20	0	31	0
August	76	2	8	0	25	0	42	1
September	18	0	2	0	5	0	17	0
October	2	0	12	0	12	0	14	0
November	16	0	8	0	7	0	12	0
December	5	0	9	0	14	0	1	0
Total	344	6	142	0	146	0	173	0
Per cent.	1.7		0		0		0.6	

O. opisthovitellinus occurs, similarly as *O. exasperatum*, in *S. araneus araneus, S. minutus, S. macropygmaeus karpińskii* and *N. fodiens.*

The intensivity of invasion amounted 4 — 5 specimens in one host, and the extensiveness was 1.7% in 1955, 0% in 1956, 0% in 1957, and 0.6% in 1958.

The life cycle in unknown, one can only suppose that, like in *O. exasperatum*, the maturation of the trematode in the final host is fairly slow. Out of 14 specimens found, only 5 were totally mature, and the others had only few immature eggs.

Similarily to S o ł t y s' data, *O. opisthovitellinus* was found only in summer both in young and overwintered animals (Table XV). It seems to me that the development is similar to that of *O. exasperatum*, and the intermediate host should be found among water snails and water insects, which metamorphose in May or in June.

Discussion

The list of the trematodes so far found in *Sorex araneus araneus* L. covers 8 species (Table XVI). In Białowieża only 3 of them were not met.

(1) *Dicrocoelium soricis* (D i e s i n g): Occurs fairly often in Białowieża, but exclusively in *Sorex minutus*, although it was described for the first time in the common shrew. P r o k o p i č 1959 mentions it as a typical steppe species, however in Białowieża it was found in *S. minutus*, i. e., the species which lives in rather wet parts of the forest than the common shrew. This could indicate, to some degree, its connection with water environment or at least with a very wet one. It is possible that in BNP another ecological variation of this species occurs.

(2) *Dicrocoelium pellucidum* P o j m a ń s k a: was found till now exclusively in *Sorex araneus araneus* in Turew, Poland.

T a b l e XVI
Trematodes parasitizing Sorex araneus araneus L.

Species	Occurrence		
	in the world	in Białowieża	
		after Sołtys	present paper
Brachylaime fulvum Dujardin	France, Switzerland, Germany, Poland, Czechoslovakia, USSR	+	+
Pseudoleucochloridium soricis (Sołtys)	Poland, Germany, Czechoslovakia, USSR	+	+
Opisthioglyphe (O.) sobolevi Shaldibin	USSR, Poland	-	+
Opisthioglyphe (R.) exasperatum (Rud.)	France, Austria, Great Britain, Poland, Czechoslovakia, USSR	+	+
Opisthoglyphe (R.) opisthovitellinus (Sołtys)	Poland, Czechoslovakia, USSR	+	+
Dicrocoelium soricis (Diesing)	France, Switzerland, Czechoslovakia	-	-
Dicrocoelium pellucidum Pojmańska	Poland (Turew)	-	-
Panopistus pricei Sinitsin	Czechoslovakia	-	-

(3) *Panopistus pricei* Sinitsin: was found till now only in North America in *Blarina brevicaudata* (Say). Prokopič 1959 mentions it in the common shrew in the mountain parts of Czechoslovakia. However, he does not include neither a description nor a drawing of the found parasites, that is why one can not be sure whether his determination was correct.

The development of the representatives of *Brachylaimidae* occurs in terrestrial snails. It is commonly accepted that only one intermediate host appears in the life cycle of these trematodes. This view is doubtlessly right with respect to many species, particularly those, the metacercariae of which are formed in sporocysts (the whole genus *Leucochloridium*). However, many investigators drew attention on the possibility of occurrence of two intermediate hosts (Joyeux, Baer et Timon-David 1934, Krull 1933, Ulmer 1951, Villella 1954).

Besides the metacercariae there were also found in Białowieża sporocysts with cercariae of *Brachylaimidae;* but they were found mostly in other snail species than metacercariae. One can suppose that two intermediate hosts, probably two different species of terrestrial snails, occur in the life cycle of these trematodes and that this phenomenon is fairly common.

The mature metacercariae come to such a degree of development that their specific determination can be stated. All the internal organs are almost developed and the morphological changes in the final host are minimal; the trematode enlarges slightly its dimensions and starts to produce eggs.

The larval forms of *Plagiorchidae* from *Sorex araneus araneus* are unknown, and they were found by the present authoress in none of the investigated terrestrial snails. Their development is probably similar to that of other *Plagiorchidae* from other vertebrates, i. e., by the presence of two intermediate hosts: a water snail and an insect which metamorphoses in a water environment. All the *Plagiorchidae* found by the present authoress show a distinct seasonal occurrence, probably connected with the biology of the intermediate host.

Metacercariae showed a narrow specificity toward the intermediate host, because metacercaria of *B. fulvum* lives only in *Zonitoides nitidus*, and that of *P. soricis* in *Succinea putris, Perforatella bidens* and *Zenobiella rubiginosa*. It can not be regarded exclusively as a result of ecological conditions, for in the same places also other snail species, and of similar size and number, have been found.

It does not mean, however, that the ecological conditions do not influence the process of adaptations to a proper intermediate host, and that in the areas, in which the snail species mentioned do not occur, these two trematode species do not have the possibilities to develop. In the materials from the mountains (Carpathians) these metacercariae were also found in other, though related, snail species. *Zonitoides nitidus* was replaced there by two common species, *Aegopinella epidostoma* (Fagot) and *Oxychylus orientalis* (Cless.), *Perforatella bidens* by *Perforatella dibothrion* Kimak., and *Zenobiella rubiginosa* by *Zenobiella vicina* (Rossm.). The substitution of one species by another one, described as parasitological vicariate, has in this case an ecological character.

The mature trematodes, contrary to the larval forms, do not show a narrow specificity towards the final host. My materials concern exclusively the parasi-

tes of *Sorex araneus araneus*, but it is known from the literature that all the trematodes of the common shrew may parasitize also other *Soricidae*. The individual species were found in the following hosts:

Brachylaime fulvum Duj.: *Sorex araneus araneus* L., *S. minutus* L., *Neomys fodiens* Schr., *N. anomalus milleri* Mottaz, *Crocidura russula* (Herm.) and *C. suaveolens* Pall.

Pseudoleucochloridium soricis (Sołtys): *Sorex araneus araneus* L., *S. minutus* L., *Neomys fodiens* Schr. and *Crocidura russula* (Herm.).

Opisthioglyphe (O.) sobolevi Shaldibin: *Sorex araneus araneus* L. and *S. minutus* L.

Opisthioglyphe (R.) exasperatum (Rud.): *Sorex araneus araneus* L., *S. minutus* L., *S. macropygmaeus karpińskii* Dehnel and *Neomys anomalus milleri* Mottaz.

Opisthioglyphe (R.) opisthovitellinus (Sołtys): *Sorex araneus araneus* L., *S. minutus* L., *S. macropygmaeus karpińskii* Dehnel and *Neomys fodiens* Schr.

The extensiveness of invasion of the common shrew is rather not high. Although in 1957 and 1958 flukes were found in 47% of the investigated shrews, the extensiveness of invasion of individual trematode species does not exceed several percent. In 1957 and 1958 it was as follows: *Brachylaime fulvum* 42.3%, *Opisthioglyphe sobolevi* 6.3%, *Opisthioglyphe exasperatum* 4.4%, *Opisthioglyphe opisthovitellinus* 1.6%, and *Pseudoleucochloridium soricis* 0.9%.

The striking preponderance of *B. fulvum* is visible. This is also the only trematode which appears in shrew throughout the whole year. It seems that this fact is connected with the biology of the parasite and its host. *B. fulvum* develops in BNP in *Zonitoides nitidus*, a small snail with a soft shell. This snail lives under the bark of fallen trees, under the litter, under the pieces of wood and is probably very well accessible as food to the shrews. Since it can be eaten by the shrews in large quantities throughout the whole year, the possibilities to be invaded by parasitizing trematode larvae are very great.

A distinct contrast is represented by *Pseudoleucochloridium soricis*. Although the metacercariae of this trematode parasitize also the terrestrial snails overwintering in soil and being also accessible to the shrew throughout the whole year, the extensiveness of invasion is very low. However, because of the scanty materials, it is very difficult to draw any conclusions from this phenomenon.

The development of the remaining three species is unknown, but we can suppose that there appear two intermediate hosts. These insects are accessible to the shrew only in certain months when they are in the stage of imago, what explains the low extensiveness of invasion with those flukes, and their occurrence exclusively in summer.

The invasion of trematodes throughout the year varies considerably. The Diagram 2 shows the invasion of one generation of shrew with all the trematode species. The diagram was made on the basis of the total materials. The curve of invasion has three peaks and two depressions. The percentage of young invaded shrews increases from June till September and then (October, November) it falls. Again in winter it increases and reaches its second maximum in January or February. The mature shrews, collected in March, are again less invaded, but just in April the curve starts to raise and in July or

August it reaches its third maximum. Then, up to the time of dying off population, the extensiveness of invasion keeps on a fairly even level. T summer-autumn peak is higher than the winter one. It is seen from the d gram that young shrews never reach the level of invasion of the overwinte animals. The peak of invasion in the overwintered shrews falls a little soo r than that of the young animals.

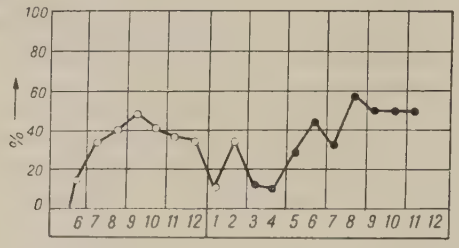

Diagram 2. Curve of invasion of one generation of *S. araneus araneus* with all trematode species (total material)

The common shrew may be parasitized by several trematode species at the same time. One trematode species occurred throughout the whole year (it was mainly *B. fulvum*), two species from June till November, and three trematode species were found at the same time only in July and August (Diagram 4).

The age of a shrew does not have a basic influence on the degree of invasion. However, certain trematode species are being easier adapted to young hosts.

Although the mature males are in summer more mobile, they do not harbour more trematodes than the females which are bearing and feeding the

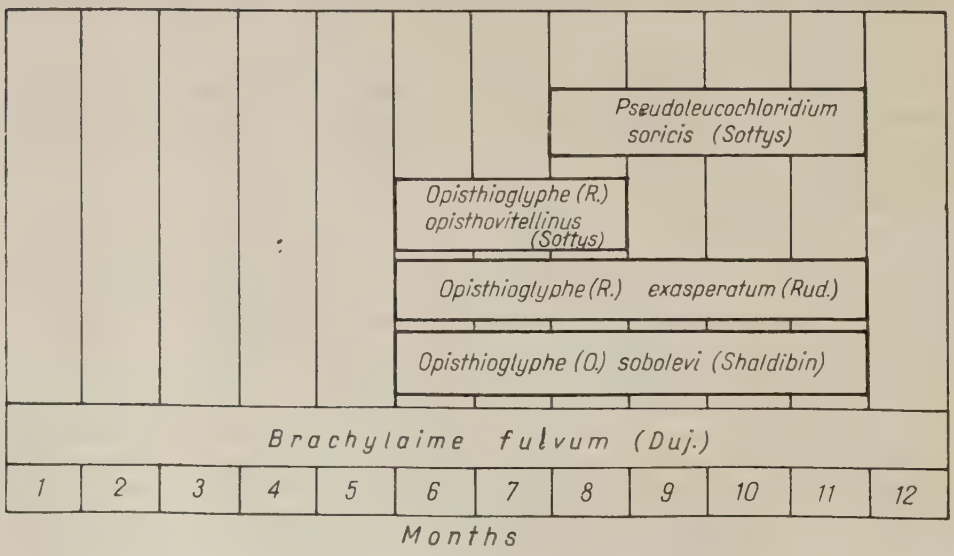
Pseudoleucochloridium soricis (Sottys)
Opisthioglyphe (R.) opisthovitellinus (Sottys)
Opisthioglyphe (R.) exasperatum (Rud.)
Opisthioglyphe (O.) sobolevi (Shaldibin)
Brachylaime fulvum (Duj.)
1 2 3 4 5 6 7 8 9 10 11 12
Months

Diagram 3. Occurrence of separate trematode species througout the year

offspring in that season. The number of collected overwintered males in May and June was as a rule higher than the number of the overwintered females, but there were not any differences in the extensiveness of invasion.

It is more difficult to explain the autumn depression of invasion. In the late autumn, in winter, and in spring exclusively *B. fulvum* can be found in shrews, though in smaller quantities than in summer. This phenomenon can be explained by two factors: either the shrews loose their parasites in autumn, or mainly the invaded specimens die in the period of „autumn death" of

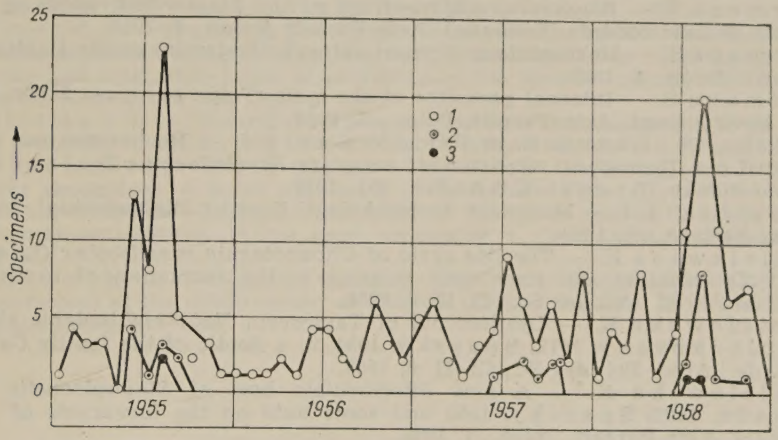

Diagram 4. Curves of invasion of *S. araneus araneus* with 1-, 2-, and 3-species ensembles of trematodes

shrews. Borowski et Dehnel 1952 suppose that the autumn death of young shrews is caused mainly by parasites. This guess, as far as trematodes are concerned, is very little probable. If the parasites could cause death of the host, this should happen in the time of settlement of parasites in the host organism, but not when a certain stability in the host-parasite system was established. The period of dying off young shrews should fall in summer months when the animals become invaded more intensively and not in autumn when the parasites already reach the maturity in the host.

It is more likely that there occurs the self-cure in shrews, what can be affirmed by the fact that the animals bred for six months in artificial conditions (in the Institute for Mammals Research in Białowieża) did not harbour as a rule any parasites. It is possible that the self-cure is caused by the natural death of parasites. The longevity of the investigated trematodes is not known; however, it is possible that they produce in autumn eggs and then die and are removed from the host body. This is complicated by the fact that young trematodes of some species were found also in November, although they were not discovered in December. This indicates that also young trematodes are removed from the host organism.

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STRESZCZENIE

Autorka przebadała na terenie Białowieskiego Parku Narodowego 805 ryjówek aksamitnych i 4437 ślimaków lądowych należących do 17 gatunków.

U *Sorex araneus araneus* L. stwierdzono 5 gatunków przywr: *Brachylaime fulvum, Opisthioglyphe sobolevi, O. exasperatum, O. opisthovitellinus* i *Pseudoleucochloridium soricis.*

Budowa znalezionych okazów była na ogół zgodna z danymi innych autorów. Ekstensywność inwazji tych przywr u ryjówki była różna, a gatunkiem dominującym jest *Brachylaime fulvum,* występujący w ciągu całego roku. Krzywa inwazji wszystkich przywr jest podobna do krzywej inwazji *Brachylaime fulvum,* który ma olbrzymią przewagę liczbową nad pozostałymi gatunkami przywr.

Metacerkaria *B. fulvum* występuje w BNP u *Zonitoides nitidus* a metacerkaria *Pseudoleucochloridium soricis* w trzech gatunkach ślimaków, głównie u *Succinea putris.*

Rozwój pozostałych trzech gatunków z rodzaju *Opisthioglyphe* nie jest znany. Jednak pewne dane wskazują, że przebiega on, podobnie jak u większości przedstawicieli tej rodziny, w dwóch żywicielach pośrednich: ślimaku wodnym i owadzie przeobrażającym się w wodzie, a przekształcającym się w imago w maju, lub na początku czerwca.

Zupełny brak większości przywr u ryjówki począwszy od listopada, oraz spadek ekstensywności inwazji *B. fulvum* w tym okresie nasuwa przypuszczenie, że ryjówki ulegają jesienią samoodrobaczeniu. Jakąś rolę może też odgrywać zmiana diety ryjówek w tym okresie (brak owadów, duża liczba nasion).